of forms of *Aglia tau*: this is followed by a more detailed account (in German and French), by Dr. Standfuss, of crossing of mutational and other forms, their relative fertility, etc.

The first 21 plates in the volume are portraits of eighteen Lepidopterists, all well-known to English entomologists, the most interesting being, perhaps, the six first, Boisduval, Herrich-Schaeffer, Rambur, de Graslin, Guenée, and Milliere, and the two last, Reverdin and Oberthür. The remaining plates we have already referred to as fully as space permits, being by M. Culot, praise of them is superfluous.

On the Correlation of Pattern and Structure in Rhopalocera with special reference to the Ruralidæ. (*With seven plates.*)

By G. T. BETHUNE-BAKER, F.L.S., F.Z.S., F.E.S.

(*The subject of a paper read before the British Association in Birmingham in 1913.*)

It is many years ago since Schoyen's discussion on *Lycaena argus* and *L. aegon* (as the two species were then called) took place, and I only mention it now because it was his papers that impelled me to undertake what had till then been a more or less spasmodic investigation, *viz.*, a thorough systematic study of the sexual armature of butterflies, and especially of that group of butterflies to which those two species belonged. I felt that we ought not to depend solely upon pattern for the differentiation of closely allied species, and I therefore at once set about making microscopic preparations of all the Palæarctic species of the *Ruralidae*. This naturally led on to a much wider field of research, extending beyond the Rhopalocera and also beyond the Lepidoptera. The taxonomic value of these organs gradually pressed itself forcibly upon me, until to-day I regard them as necessary to the correct grouping of the *Ruralidae*, and probably (I do not say certainly) of other families of Rhopalocera, if not of the Lepidoptera as a whole, so that in any cases of doubt after the neuration, I should first investigate the sexual organs.

Long continued study of these organs gradually brought to light the fact that a *marked* change of form in them was also accompanied by a change in pattern in the species and the genus. From the very beginning I had learned that there were small specific differences, but it was only a wide experience that could show their value from the taxonomic point of view, and it is this view, especially, that I want to lay before my readers, *viz.*, that so far as the *Ruralidae* in their widest sense are concerned, it is a fact that change of structure is accompanied by change of pattern, or, *vice versa*, change of structure accompanies change of pattern.

As my first instance may I give one of the species already mentioned, *Plebeius argus* (the type of the genus *Plebeius*), and compare with it an allied genus *Celastrina*, whose type is *argiolus*. The difference in colour is at once apparent, whilst the pattern of the underside is very diverse.

These distinctions are followed by an equal change in the male armature. *P. argus* (Pl. xiv., fig. 1), has the longish clasp, the gently projected (backwards) girdle, the tegumen strongly bifid and very narrow in front with strong falces or hooks, and with the apical hood fairly broad. In *C. argiolus* (Pl. xiv., fig. 2), the clasp is totally

different, being sharply excavated beyond the centre and terminating in a long dagger-shaped point, the girdle is suddenly projected backwards, and the bifid fore-part of the tegumen has very copious broad cheeks without falces, whilst the apical ridge is much elevated and reduced to a very narrow saddle. The ædœagus is also quite different in shape.

Everes argiades (Pl. xiv., fig. 4), may be taken as somewhat near to *C. argiolus*, but again the colour and underside pattern show a different development, and this is more strongly marked in the armature, whilst the neuration also differs slightly. The marked difference in the clasp will be seen at once, as also in the tegumen, but the ædœagus is nearer. At the same time, if we refer to the clasp of *argiolus* and also of *puspa* (Pl. xiv., fig. 3), the process of the development of the clasp of the genus *Celastrina* towards *Everes* is quite evident, *viz.*, the curving downwards of the long spike of the upper margin so as to form the long recurved hook of the latter (*Everes*). The tegumen is very diverse being greatly reduced with its greatest development along the dorsal line, whilst the cheeks are much reduced, and have short spikes in place of the falces, these being of the most reduced form of this organ that I know of in the group.

The nearest species in pattern to this genus (omitting the genus *Cupido*, which is an Everid) is perhaps *Glaucopsyche cyllarus* (Pl. xiv., fig. 5,), but the male armature differs and the colour and pattern are in reality different from both though difficult to describe in words. The clasp is large and heavy, and in its termination is a modification of both the previous ones; the tegumen is very near *Celastrina*, in fact it might belong to it were it not that it has well developed falces, whilst the ædœagus is nearer to *Everes*. Our beautiful English large blue *Lycaena arion* belongs to the same section as *Glaucopsyche cyllarus*. I only bring it forward now (Pl. xiv., fig. 6), to show how a marked development of pattern may be accompanied only by a small alteration in structure when it occurs within its own sub-family. In the former the difference in pattern is well known. In the armature, however, the clasp is yet larger and heavier (squarer), the terminal hook is also more heavily developed, and the tegumen is decidedly further away from the Celastrinid group. The dorsal part of it is not excised to anything like so great an extent, and the lateral cheeks, which are provided with very long and strong falces, are unusually large and square. The ædœagus does not differ materially from the species last described, this however we should expect, *Glaucopsyche* belonging to the *Lycaena* group in its strict sense.

Scolitantides orion (Pl. xiv., fig. 7), brings in another group of the *Plebeiinae* with several genera, but the one species will be sufficient for my purpose. The pattern is quite different to any of the others. The prehensores are likewise different, the clasps being very simple, of moderate length and width, and evenly rounded at its termination, not being divided into two sections at its apex, as so many are. It would have (one would imagine) but little grasping power. The tegumen is of a reduced Celastrinid type, but with regular Plebeiid hooks. The ædœagus is very different, though it has the Everid little spikes at its lower extremity; the fulcrum, however, is very highly developed, being very long and deeply curved.

Callophrys rubi (Pl. xv., fig. 8).—Our common Green Hairstreak is

well-known with its plain brown upperside and green underside. Its male armature consists of a rapidly tapering, wedge-shaped clasp, without any fulcrum (a characteristic of the *Ruralinae*), the tegumen ample, with broad, lateral cheeks moderately excised, and long formidable falces, whilst the ædœagus is very long indeed, and very narrow. The abundance of long strong bristles on the clasp and tegumen is also an important feature in this genus. Very similar, indeed to it, so far as these organs are concerned is *Satsuma friraldszkyi* (Pl. xv., fig. 9), though much different in pattern, the upperside being blueish, and the underside dull brown and somewhat mottled; at the same time there are also differences in the prehensores. The wedge-shaped clasps are much broader, the tegumen is less ample and proportionately more excised on the dorsum, whilst the falces are heavier and stronger.

Strymon titus (the type of the genus) (Pl. xv., fig. 10), is easily recognisable by its *spotted* underside. The genitalia differ also in their erect position in the shape of the clasps, and in two (so far as I know) quite unique shields extending on two strong arms from the girdle (one shield being developed from each side of the girdle). I bring this forward to show a specific difference rather than a generic one.

Strymon w-album (a close relation of our British *w-album*) (Pl. xv., fig. 11,) is distinct in colour and pattern with its chestnut coloured patch on the upperside and the fine white lines on the underside, but the male armature proves it to be closely allied to the previous genera. It has, however, no saccus at all, which is an important character in this order.

Neolycæna tengstroemi (Pl. xvi., fig. 12), is abundantly distinct in its shape and in the somewhat Plebeiid type of markings on its underside, the genitalia, however, show at once its alliance to this section. The small narrowish clasps and the long aedoeagus bring out this prominently, the tegumen however is very different having very unusually copious laterals, the falces are very large with a bold deep curve, whilst the girdle is very short.

Thestor fedtschenkoi (Pl. xvi., fig. 14), and all in its genus show great differences in pattern, but again the armature is peculiarly Strymonid. The clasp is much longer and finer, and the tegumen differs slightly, whilst the neuration also differs, it having an extra subcostal vein in the primaries. *Ruralis quercus* (Pl. xviii., fig. 21), is entirely different in pattern and colour as also in the structure of the genitalia, its alliance to the genus *Neolycæna* is shown in the large hooded tegumen, its deviation in the shorter, thicker and differently shaped ædœagus, whilst the clasps also differ entirely in general pattern.

In colour *Laeosopis roboris* (Pl. xvi., fig. 15), is very close to the previous species though in the underside pattern it is very distinct. This change is likewise carried on in the genitalia, the tegumen being unique, I believe, in its quite vertical position instead of being horizontally placed. The ædœagus is shorter still, whilst the clasps are also further reduced, though they are sufficiently near to *quercus* that if we were to cut off the prolongation at the upper apex of the clasp of that species we should approximate to those we are now considering.

I have brought *Cigaritis zohra* (Pl. xvii., fig. 16), in at this point to show its correlation with the *Heodinae* on the one hand in its general colour, and with the *Ruralinae* and *Plebeiinae* in structure on the other hand.

The erect girdle is quite Strymonid (*i.e.*, Ruraline) its clasps partake of an admixture of the *Ruralinae* and the *Plebeiinae*, whilst its deeply cleft tegumen approaches the Plebeiid pattern, and it may also show some approximation to the quite peculiar and reduced structure of that organ in the *Heodinae*. In the pattern of its underside it may have some affinities to the *Plebeiinae* already referred to, it has much more to some exotic genera, but its colour is very close to that of the genus *Heodes* to which I will now refer in the species *phlaeas*, a species which is found almost over half the world, extending right across Asia into Japan and India, and going westward through the Madeiras over a large part of North America. Its relation in colour is evident, though the underside pattern differs from it considerably. This, however, in the group of insects we are dealing with, is of great importance, both from the phylogenetic and also from the taxonomic point of view. The tegumen (Pl. xvii., fig. 17), is very specialised, consisting as it does of two lateral narrow lobes attached to each other merely by the girdle and having no dorsal chitine beyond the narrowest collar, joining the two sides of the girdle. Attached to these lobes are the usual falces, but instead of being connected to the cheeks of the tegumen near the front, they are attached right at the rear. The clasps are very broad, expanding somewhat in the front with an evenly curved and sharply serrated apex, though the serrations are very small. From the base of each clasp in this series, a peculiar super-structure arises of a wedge-shape that inclines forward over the clasp and reaches to near its centre. This is peculiar to, and typical of, the genus *Heodes*, though, in other species, it assumes a very different form. The ædœagus will be seen to be somewhat bulbous at the base, but very rapidly tapering to its tip, where it ends in a fine point. The tegumen, the ædœagus, and the super-structure of the clasp are entirely peculiar to the *Heodinae*.

In *Heodes thetys* (Pl. xvii., fig. 18), the male armature assumes its extreme form, and is in its general lines a very beautiful object. The tegumen is not so bulky, nor are the falces; the girdle is long and elegantly curved; the clasps also are more delicate in form, being of a somewhat long pear-shape, the thick end forming the base, whilst the apex is curved upwards and sharply serrated, forming a broad hooked extremity. The super-structure assumes in this species its highest development, and consists of two long, narrow, boldly and beautifully curved arms terminating in a fine tip. The ædœagus is equally elegant in shape, having a somewhat elliptical base, the tubular three-quarters gradually tapering into a fine point, and being curved and re-curved at its tip. The colour of the insect is brilliant, spotless, lustrous, reddish-copper, whilst the underside is the softest toned design in the group, and is somewhat different to all its near allies. In the same genus is a small section of purplish species, that from their small size and colour look very different indeed, but their underside markings show them to belong to the same genus as the others. The little butterfly *Heodes sarthus* is found in the Eastern Turkestan, and in the Pamir Mountains. The difference in colour and pattern speaks for itself. We find, however, some change in the male armature (Pl. xvii., fig. 19). The tegumen (an important character from a taxonomic point of view) is quite similar in general structure to all its allies, as also is the ædœagus, though in this a modification in shape is to be

observed, but the clasps are very different, there being a considerable change of shape in them, whilst the super-structure comes nearer to our common British *phlaeas* than to the general form. I have mentioned these three species of one genus so as to show specific variation of armature with also small variation of colour. We will now take three species of marked difference in colour into consideration. *Ruralis betulae* with an entirely brown male and an orange spotted female, *R. lutea*, which is entirely orange in both sexes, the underside of these two being very closely alike, and a brilliant metallic green species *Ruralis orientalis* with a different underside closely allied to *Ruralis quercûs*, already referred to (see *antea* p. 179). *R. betulae* (Pl. xviii., fig. 20), has a very large hooded tegumen, not excised on the dorsum at all, with large strong falces attached to its lower front extremities; the girdle is broad, strong, erect, deeply excised at rear; the ædœagus is small, rather short, straight, somewhat tapering, whilst the clasps are very small and broadly oval with no processes. This is the type of the genus. In *R. lutea* (Pl. xviii., fig. 20A), the tegumen remains the typical, unexcised, hooded-shape, but it is much smaller in its dimensions, the falces being also much smaller; the ædœagus is very large and similar in general shape and size to *quercûs*, the girdle and the clasps also are more nearly allied to *quercûs* than to *betulae*, the clasps having a protruded lobe-like process at their upper apex. In *R. orientalis* (Pl. xviii., fig. 22), with its underside pattern so closely allied to *quercûs*, we find the armature rather nearer to *betulae* than to *quercûs*. The hooded tegumen is more ample, the ædœagus is quite close in shape to the small ædœagus of *betulae*, whilst the clasps, though larger than *betulae*, are nearer to that species than to *quercûs*. The variation of species *inter se* has thus been demonstrated, but it will also be advisable to examine two other cases of specific *inter se* variation, in cases where species are very different superficially, but where their armature is so close that only a very expert eye would observe anything to raise a doubt in his mind—and cases where the imagines are exceedingly close superficially, but the male armature is less so. Professor Poulton has drawn my attention to this, and has enabled me to show this little group of African species of the genus *Acraea*. These species do not affect my main argument, but they are most interesting in showing that specific variation occurs* also in the genus *Acraea*, as one would expect, though it seems to proceed on different lines to what occurs in the *Ruralidae*.

In *Acraea zetes* and *A. chilo* we have two species that appear very different superficially, the former with its entirely blackish primaries and heavily marked secondaries, the latter pinkish tawny in both wings. If, however, we examine the spots of the wings we find they are very close indeed. Eltringham in his able monograph places them next each other and we find the armature is so close that it needs a critical examination to discover the differences that, as a matter of fact, do exist. The two species are as nearly the same size as can be, but the armature of *zetes* (Pl. xviii., fig. 23), is decidedly smaller than that of *chilo* (Pl. xviii., fig. 24), the uncus and tegumen are

* By specific variation I mean variation between species *inter se* of the same genus—not that the same species has differentiation in armatnre, this I have not found.

slightly different in shape, the girdle of *zetes* is more erect and decidedly slighter, the pilosity of the clasps is markedly diverse from that of *chilo*, being much longer, thicker and heavier, whilst the œdœagus of *chilo* is longer and different in shape in the basal area. The saccus also is quite different in the two insects. The species *look* very different, they are, however, very closely allied, and the armature follows their specific relationship, not their superficial facies. This is as we should expect. Again there are two forms *A. natalica* var. *pseudegina* (Pl. xix., fig. 25), and *A. natalica* (Pl. xix., fig. 26), as also *A. acrita* var. *ambigua* (Pl. xix., fig. 27), and *A. acrita* var. *pudorina* (Pl. xix., fig. 28). Both these two pairs are decidedly different, but we have in each case *natalica* and its various races, and *acrita* with its various races, so that in the light of Mr. Eltringham's monograph, we might quite properly call them two polymorphic species, with wet and dry forms and intergrades almost all along the line. In these cases we should not expect their structure, such as neuration or armature to change, and so it is, the structure remains true though the colour differs. It is a case of that unknown quantity *x* in the constitution of the species (would that we could find out what *x* is) that under different conditions causes the mutability of species, the most interesting factor of it being why some species respond and why others do not.

This brings us to the second and last instances I have to draw attention to, *viz.*, similarity of design but difference in structure. In *Acraea periphanes* var. *acritoides* (Pl. xix., fig. 29), and *A. acrita* (Pl. xix., fig. 30) we certainly have a superficial, a very superficial, resemblance, but the armature is very different. At the same time I must say that no experienced entomologist would hesitate in at once separating the two species; some of the spots in the secondaries assume quite different positions. With *Acraea calderena* (Pl. xx., fig. 31), and *A. pudorella* (Pl. xx., fig. 32), the case is more interesting; they had always been considered forms of one species so exceedingly close were they, and I think it was due to Mr. Eltringham (I speak under correction) that they were discovered to be distinct species, his armature dissections proving this. At the same time the postmedian line of spots is quite different in the two insects, and it was this, no doubt, that induced the query in Mr. Eltringham's mind. In *A. chambezi* and *A. mansya* the difference in the perfect insects, the absence of many spots on the upperside in the latter, would at once lead one to expect the divergence of armature that we see (Pl. xx., figs. 33, 34).

Finally I would refer to the genus *Amauris*, to the two species *A. echeria* var. *jacksoni* (Pl. xx., fig. 37) and *A. albimacula* var. *hanningtoni* (Pl. xx., fig. 38), and also to the species *A. danfeldti* and a new species from Angola that I call *A. angolae*. The first two are separable only by the size and shape of the sexual brand on the secondaries and by the palpus of the first being spotted, whilst the second is streaked. *A. angolae* and *A. danfeldti* are separable in precisely the same way, but their colour is white and black, instead of being more or less yellowish, as in the other case.

The male armature differs likewise (Pl. xx., figs. 39, 40), the contour of the clasps differs in each species, whilst the terminal sternite, which in this genus is furnished with very formidable teeth, differs in the shape, in the size, and in the abundance of teeth. This last character

is of much interest, for it is a feature I have not found in any other butterfly that I have examined.

In considering the whole question, however, it must be borne in mind that as there are generic resemblances and specific resemblances so there are both generic and specific differences, and they do not necessarily pass along the same line. Investigation has taught us that in the *Ruralidæ*, in its broadest sense, the tegumen is of dominant generic value, that the ædœagus and the harpagines (clasps), so far as their general form goes, are also of generic value, but in both of the latter mutation occurs which is purely specific, rarely with the ædœagus but regularly with the harpagines, whilst so far as specific divergences are generally concerned, the clasps are the most sensitive, and it is in these organs that we find the smaller or larger differences that are observable between species and species. I have referred to two genera that are evidently in a period of marked mutation, *Heodes* and *Ruralis*. In both cases it was seen that the clasps were altering considerably in different sections of the genera, and that this had been possibly concurrent with alteration of colour and pattern, but that at present, though colour was already different, yet the structure of the imagines, in their form, their neuration, and other characters had practically changed but little. The male armature, however, showed definitely that mutation was in progress, and that both genera are evidently in the process of splitting up. For the present, however, there seems nothing tangeable, except the colour, whereby it would be possible to divide them, and colour is too unstable a feature on which to break up an otherwise thoroughly homogeneous family. I have said that the altering of the clasps may have been concurrent with colour; as a matter of fact, I believe that colour is much more sensitive to mutation than structure, and that any mutability in the structure follows, rather than is followed by, mutation in colour and pattern.

My only really thoroughly exhaustive study has been on the *Ruralidae*, but from a very considerable number of dissections made by myself in other families, the same result occurs more or less in most of the Rhopalocera, and I am now led to believe that pattern is very generally correlated with structure.

Explanation of Plates XIV.-XX.

All the figures are magnified ×30, except those of the genera *Acraea* and *Amauris*, which are ×7.

Plate XIV.

Fig. 1. *Plebeius argus.*
,, 2. *Celastrina argiolus.*
,, 3. *Celastrina puspa.*
,, 4. *Everes argiades.*
Fig. 5. *Glaucopsyche cyllarus.*
,, 6. *Lycaena arion.*
,, 7. *Scolitantides orion.*

Plate XV.

Fig. 8. *Callophrys rubi.*
,, 9. *Satsuma frivaldszkyi.*
Fig. 10. *Strymon titus.*
,, 11. *Strymon v-album.*

Plate XVI.

Fig. 12. *Neolycaena tengstroemi.*
,, 13. *Thestor ballus*, (not mentioned in text).
Fig. 14. *Thestor fedtschenkoi.*
,, 15. *Laeosopis roboris.*

PLATE XVII.

Fig. 16. *Cigaritis zohra*.
,, 17. *Heodes phlaeas*.
,, 18. *Heodes thetys*, (ædœagus upside down, apex of one clasp cut off, for clearness, and falces of tegumen misplaced.)
Fig. 19. *Heodes sarthus*.

PLATE XVIII.

Fig. 20. *Ruralis betulae*.
,, 20A. *Ruralis lutea*.
,, 21. *Ruralis quercûs*.
Fig. 22. *Ruralis orientalis*.
,, 23. *Acraea zetes*.
,, 24. *Acraea chilo*.

PLATE XIX.

Fig. 25. *Acraea natalica* var. *pseudegina*.
,, 26. *Acraea natalica*.
,, 27. *Acraea acrita* var. *ambigua*.
Fig. 28. *Acraea acrita* var. *pudorina*, (uncal extremity broken off).
,, 29. *Acraea periphanes* var. *acritoides*.
,, 30. *Acraea acrita*.

PLATE XX.

Fig. 31. *Acraea caldarena*.
,, 32. *Acraea pudorella*.
,, 33. *Acraea chambezi*.
,, 34. *Acraea mansya*.
,, 35. *Acraea pudorella* var. *detecta* (not referred to in text).
,, 36. *Acraea pudorella* (not referred to in text).
,, 37. *Amauris echeria* var. *jacksoni*.
,, 38. *Amauris albimaculata*.
,, 39. *Amauris danfeldti*.
,, 40. *Amauris angolae*.

SCIENTIFIC NOTES AND OBSERVATIONS.

ON ELACHISTA POAE.—I have been breeding this Tineid and can add a few points to Stainton's account (*Nat. Hist. Tineina*, vol. iii., p. 104). On May 10th, 1914, most of the larvæ had already pupated, however, I found a couple of larvæ on the eve of pupation as late as May 27th. The imagines emerged from May 23rd onwards, nearly always in the morning. I have the actual hour of emergence noted in a few cases, 8.30 a.m., 8.45 a.m.; and one as late as 10.0 a.m., but that is exceptional.

The insects were found along the banks of the River Granta, above Cambridge. The pupa is generally about two feet above the water. It is frequently on an uneaten leaf, so we presume the larva wanders about when full-fed. Once only, out of sixty cases observed, did I find two pupæ on one leaf. The pupa is invariably head upwards on the concave side of the leaf-lamina of *Glyceria*, sp. A slight cocoon is formed, frequently when the leaf is still young. The cocoon bridges across the space between the two sides of the partially folded leaf, and as the leaf grows and becomes flatter the cavity of the cocoon is reduced and the whole structure is not seldom ruptured. This does not appear to harm the pupa. The cocoon varies in vertical length from 11mm. to 18mm., and in breadth from 6·5mm. to 8mm. It is extremely frail, and formed of white silk, nearly all the strands of silk run transversely from one side of the leaf to the other. The cocoon forms a "blanket" over the pupa, and there is no inner cocoon. The tail of the pupa is attached, I suppose by means of hooks, to a small dense web under the lower end of the "blanket." The upper end of the pupa is absolutely free but retains its perpendicular position by virtue of thin fixation of the tail, and also because the pupa is very stiff. This position is not affected by the accidental rupture of the "blanket."